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EDUCATIONAL TECHNOLOGY PROGRAM

Frederick C. Frick

Massachusetts Institute of Technology

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Design of the microfiche selector/reader breadboard for LTS-4 is progressing on schedule. An experiment to evaluate pin positioning as an alternative means of vernier positioning has also been initiated. Results of the data demodulation tests begun in the previous quarter indicate that the system will support a 1200-baud data rate.

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15 December 1972

F. C. Frick
Program Manager

Accepted for the Air Force
Joseph J. Whelan, USAF
Acting Chief, Lincoln Laboratory Liaison Office

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EDUCATIONAL TECHNOLOGY PROGRAM

I. APPLICATIONS RESEARCH FOR THE LINCOLN TRAINING SYSTEM

A. Continuation of the Keesler Trial

Data showing the value of the LTS in technical training at the Keesler Technical Training Center were reported in the preceding Quarterly Technical Summary. The data indicated equal achievement and 37 percent less training time for LTS instruction over conventional classroom instruction. The students who participated in the study represent the lower 80 percent of the students entering the fifth week of the ATC Standard Electronic Principles Course. Students ranking in the upper 20 percent according to these criteria were not represented because they normally work individually with conventional materials and pace themselves. Results of this group on LTS have been obtained recently.*

Incoming students in the upper 20 percent were assigned randomly to either LTS instruction or self-paced instruction, 30 in each group. Both groups studied materials that ordinarily occupy one 30-hour week in the classroom, and then took the achievement test. During the next week, all the students paced themselves using conventional materials, after which they took another test that covered both weeks.

All test scores to date are summarized in Table I. The main finding is that the upper 20 percent of students achieve at a higher level than regular students only if they are on LTS. The total completion time distribution is shown in Fig. 1. The upper 20 percent of students showed an added saving of 25 percent attributable to LTS over the usual saving of 45 percent relative to 30 hours allotted in the classroom. It is apparent that high-aptitude students, as well as the regulars, benefit substantially from the individualized, tutorial instruction delivered by the LTS medium.

B. LTS Simulation Study

An effort is being carried out for the Human Resources Laboratory, Technical Training Division, Lowry AFB, to study the applicability of LTS to simulation in training. As a result of a survey of courses offered at Lowry, it was determined that a widespread need was "task simulation." Two demonstration lessons in this area have been developed during this quarter.

A 40-frame procedure has been developed for calibrating the Tektronix Model 545-A Oscilloscope by photographing a specialist while he performed the required calibration. Supporting audio was provided based on the technician's commentary while working, and frame branching logic was included to allow for interactive support.

A second lesson was obtained which is a simulation of the trouble-shooting task. The program, provided by the University of Kentucky Dental School, involves the test, diagnosis, and treatment of endodontic disease. The situation is analogous to test, diagnosis, and repair of equipment, and the instructional strategies are the same. The lesson includes auxiliary audio/visual displays and it is known to teach. It was selected because there exists a substantive CAI program of this sort in actual school use and the feasibility of the transfer of a conventional

* Reported in "Training High Aptitude Self Paced Students on the Lincoln Training System (LTS)," Keesler Project Report 72-118 (28 November 1972).

TABLE I

MEAN SCORES FOR FOUR GROUPS ON TWO TESTS

Aptitude Level	Method of Instruction First Week	N	Mean Training Time (hours)	Mean First Test Score (percent)	Mean Second Test Score (percent)
Upper 20 percent	LTS	30	12.4	93	88
	Self-paced	30	16.4	80	83
Lower 80 percent	LTS	55	18.9	80	79
	Conventional	55	30.0	77	78

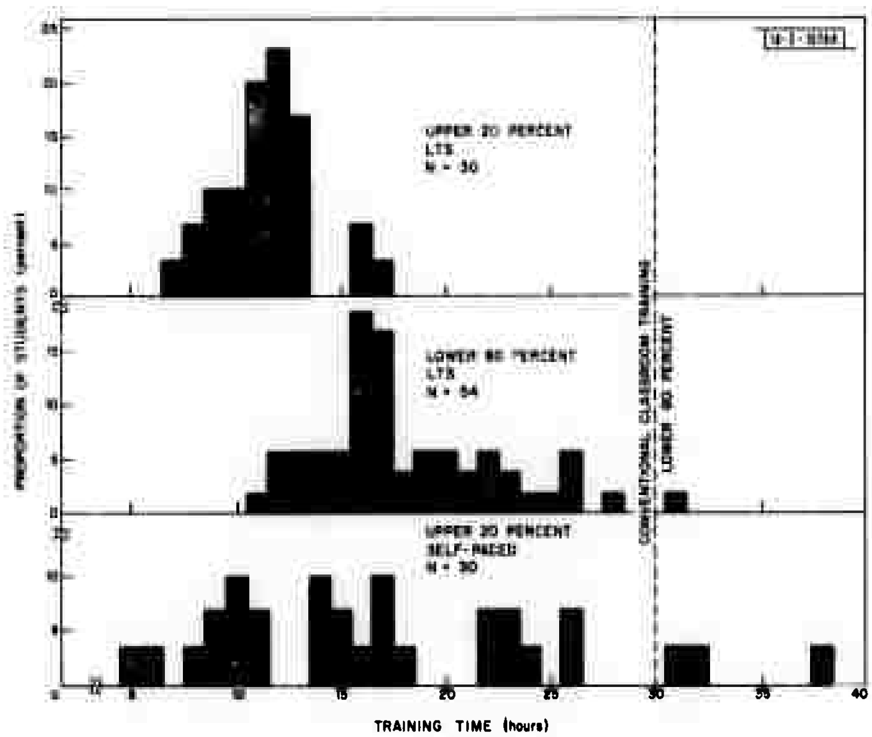

Fig. 1. Distribution of time spent taking instruction in fifth week of Electronic Principles Course. Three distributions are identified by student aptitude level and meth of instruction.

CAI program to the LTS could be demonstrated. The displays and interactive support of student learning were preserved in every detail.

During the next quarter, results for a few students on the oscilloscope lesson will be obtained. A cost-benefit analysis for both lessons, comparing LTS with other systems, will be carried out. A summary report on all the results will bring this effort to a close.

C. New Student Response Interpretation Feature

Most instructional applications are well served by frame selections which depend only on the student's current response. There are special occasions, however, when an author would like to program LTS on the basis of a series of recent responses. Frame selections which depend on the student's cumulative performance would be useful in the following applications, for example.

- On-the-job equipment maintenance: the technician is instructed to perform a series of tests and to give their results to the LTS, which decides eventually whether or not a given condition exists. Thus, the system not only guides the technician but also relieves him of memory and decision functions.
- Efficient pre- and post-tests of skill and knowledge: the student answers a series of questions and receives immediate feedback for each answer, but the length of test is conditioned by the error rate or by error type. Thus, the system allows for tests which are individualized in terms of both content and time.
- Simulating clinical diagnosis and treatment: the advanced medical or dental student "performs" a number of diagnostic procedures and then gives his diagnosis, which elicits from the LTS feedback on its accuracy. He is also told whether the procedures that he selected are relevant to the patient's problem. Thus, the system allows the student's choice behavior to unfold completely without interruption and prior to machine assessment.

The author-control programs of the LTS were modified to permit delayed feedback – that is, frame selections which are based on a count of student responses. An action occurs when a cumulative index of responses made in one of several areas exceeds criteria and the student is transferred to another frame sequence. This feature has been implemented for test in new lessons.

II. LTS-4 HARDWARE DEVELOPMENT

During this quarter, the microfiche selector/reader breadboard design has continued. The opto-mechanical system design is nearing completion, and the major components have been released for fabrication. A system for dynamically measuring the relative modulation transfer function (MTF) of optical components and detectors was assembled and used to measure the MTF of the reader lens.

An experiment is being implemented to evaluate pin positioning as a means of vernier positioning the microfiche. The test bed is a modified LTS-3 terminal which will be cycled under computer control to simulate lifetime wear of the film and mechanical components.

A copy of the reader system image rotator has been ordered which will permit alignment tests and implementation of an alternate reader using an LED as a light source. A reader employing a rotating microscope scanner with an LED light source and pin positioning is being designed.

Results of data demodulator tests to date indicate that the system will support a 1200-baud data rate. Using a 2-out-of-3 majority decoding technique, described earlier, the bit probability of error is less than 10^{-8}.

Mock-up consoles are being constructed to evaluate front and rear projection screens under simulated LTS-4 operating conditions. Visual materials will be viewed at typical working angles and distances to determine user preference for background illumination levels.

The Intel SIM4-02 microcomputer components and MP7-02 programming module have been assembled and checked out. Programmable read-only memories (PROMs) have been coded with the logic program described in the previous Quarterly Technical Summary and debugging is under way.

A. Fiche Selector/Reader Breadboard

Design and construction of the fiche selector/reader breadboard continued during this quarter. The baseplate casting was designed and fabricated. The image rotator, bearings, lens mounts, servomechanisms, and control electronics were constructed, and subassembly tests have begun. System tests of the breadboard are expected to begin in early January 1973.

An optical sensor assembly (OSA) that detects sound-track modulation and develops the track error signal for the radial drive servo loop has been procured and tested. A low-noise photo current signal amplifier and low drift track amplifier have been designed and tested for use with the OSA.

The radial tracker servo system consists of the OSA mounted on a linear actuator drive assembly (a rotary-to-translational converter) and a conventional DC servomotor/compensation amplifier.

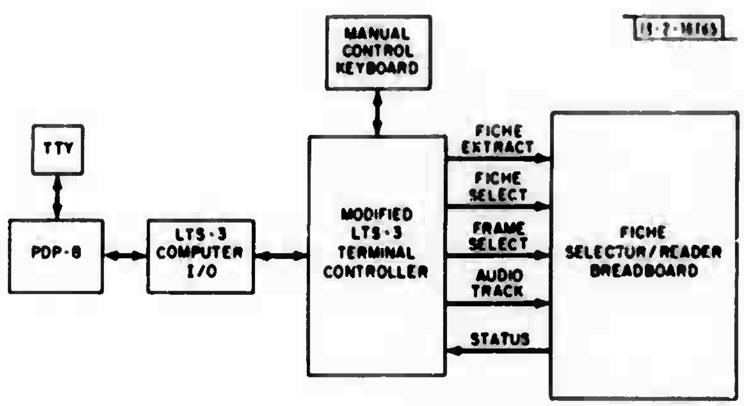

Fig. 2. LTS-4 breadboard control system.

In order to fully test the breadboard fiche selector/reader, a digital control interface has been constructed which uses much of the existing LTS-3 control and processing equipment. A functional block diagram of the breadboard system is shown in Fig. 2. The system performs four basic functions:

(1) Fiche extraction: transfer of fiche from read position to cassette.

(2) Fiche selection: transfer of selected fiche from cassette to read position.

(3) Frame selection: x-y translations of fiche to place desired frame under reader optics followed by fine x-y registration.

(4) Audio track: acquisition and track of spiral image.

The system may be operated manually or under computer control. The LTS-4 model requires that a frame position command be in the form of a signed magnitude of change in Row position, from the previous frame, with an exact column position of either 0 or 1. As each new fiche card is loaded for operation, it will be positioned at column 0 Row 0, which will define an initial reference for following frame change commands on that fiche. This LTS-4 requirement was implemented in hardware.

The LTS-3 card cycle diagnostic test program has been modified to comply with LTS-4 model timing, data format, and control requirements.

B. Pin-Positioning Experiment

A pin-positioning method of vernier film registration is being investigated which, if practical, can eliminate some of the optics and electromechanical control described above. When locating the audio record on the fiche by pin positioning only, the total location error is made up of the following:

(1) Precision in the manufacturing of the fiche,

(2) Temperature-humidity variations in the field affecting the fiche,

(3) Play and wear in the registration mechanism of the reader,

(4) Manufacturing accuracy of the registration mechanism of the reader.

By manufacturing the fiche with care and through careful design of the system and proper selection of material, a total centering accuracy of 0.002 to 0.004 inch can be maintained by pin registration.

The repeatability and wear characteristics of a pin-registration system are being investigated. Pin registration has been added to an LTS-3 terminal. A test program has been written for use in the pin-positioning experiment. The location accuracy of each frame will be measured after a number of repeated frame access cycles, using a special registration fiche and a calibrated microscope. From these data, the re-registration and wear characteristics of the system will be derived.

C. MTF Measurements

A special-purpose lens MTF measuring system was constructed during this quarter, using a simulated LTS-4 optical transmission system. The condenser system and light source from an LTS-3 as well as the light detector were employed. The lenses are tested at the design conjugates (image-to-object distance), and the detector is placed at the design location in the field of the lens.

Three carriages were built for the bench. The first carries the condenser system, a servomotor with a separate tachometer, and a rotating photographic glass plate. The second carriage carries a lens mounting system which can translate in three axes, rotate about a vertical axis, and has interchangeable lens mounting plates. The third carriage carries a photodetector on a calibrated microscope stage to place the detector at specific locations in the field.

The method of measuring MTF using film grain noise is analogous to the measurement of filter bandwidth using a white noise source. High-resolution film has a spatial noise spectrum approximately equal to the film MTF and is essentially flat in the range 0 to 60 cycles per mm. The rotating emulsion causes variations in the locally transmitted light which, when imaged through the test lens and sensed by a narrow photodiode aperture, result in related time-varying photo currents. The temporal photo current spectral frequency is related to the spatial transmittance spectral frequency by

$$f_t = R\omega\nu_s \quad ,$$

where f_t is in Hz, R is the radius in mm, ω is the rotational velocity in rad/sec, and ν_s is the spatial frequency in c/mm. A temporal spectrum analyzer measurement can be directly converted into a system MTF and, by deconvolving the aperture MTF, the lens MTF is obtained.

D. Data Channel Experiments

An LTS-3 has been modified to permit branching data to be read from the audio spiral. Measurements made at 1200 baud (400 bits/sec) yield a baud probability of error of less than 2×10^{-5} on the Kalvar copy film. This implies a bit error rate of about 10^{-9}.

The spiral tracker gain is a decreasing function of percent amplitude modulation at large tracking errors. During acquisition, when large track errors are present, the percent amplitude modulation should be zero to minimize the potential loss in track performance due to a decrease in gain. At present, the data preamble is recorded over the initial ±2 track x-y acquisition uncertainty. This modulation can be eliminated if a carrier detect circuit is used to turn on the data demodulator or if acquisition can be guaranteed after a fixed time delay by means of a lead-in spiral. A carrier detect circuit was added to the data demodulator to permit the spiral tracker to acquire an unmodulated spiral. Initial tests on silver halide masters indicate that carrier detection will add no more than 100 msec to the data acquisition delay. For LTS-4, a lead-in spiral will be tried. This has the additional advantage of reducing the total delay due to x-y access error to 1/2 sec.

For LTS-4, the data are recorded near the outer diameter of the spiral. For some applications, it may be desirable to record the data toward the end of the spiral or over the entire spiral. Spirals have been recorded with the data recorded at various diameters from o. d. to i. d. to study the effects of decreasing resolution on data reliability. Initial tests on silver halide master fiche indicate that data retrieval over the entire spiral is feasible.

E. Front-Rear Projection Screen Evaluation Facility

Two types of mock-up consoles will be built – one front projection and one rear projection – for the purpose of evaluating front projection screens and rear projection screens and for the purpose of comparing front and rear projection under assumed LTS-4 operating conditions. The consoles will be designed with identical projection systems and frame size will be approximately equal to LTS frame size. By viewing typical material (resolution and acuity charts, text, detailed black-white and color photographs) at typical angles and distances, screens can be ranked on a relative efficiency basis (relative input power to attain same quality) for various ambient background illumination levels. Both mock-up consoles will be designed to be consistent with LTS-4 geometrical constraints. The initial design and experimentation should give a reasonable picture of the trade-offs between front and rear projection.

F. Self Processor

Work continued during this quarter to construct, program, and debug the simulated LTS-4 processor. An ASR33 teletype was procured for use with the Intel MP7-02 programmer module for programming the SIM4-02 programmable read-only memories (PROMs). A PDP-8 program was written to convert paper tape programs from binary format to MP7-02 P/N format for programming PROMs via the ASR33 TTY. The serial data input, parallel data (PDP-8 logic) output and keyboard input interfaces with the SIM4-02 are completed, and initial checkout has started. The first two programs, written for SIM4-02 operation as an LTS-4 processor, have been coded in MP7-02 P/N format, loaded in PROMs, and initial debugging of the program operation has started. A flow chart for programming PROMs is shown in Fig. 3.

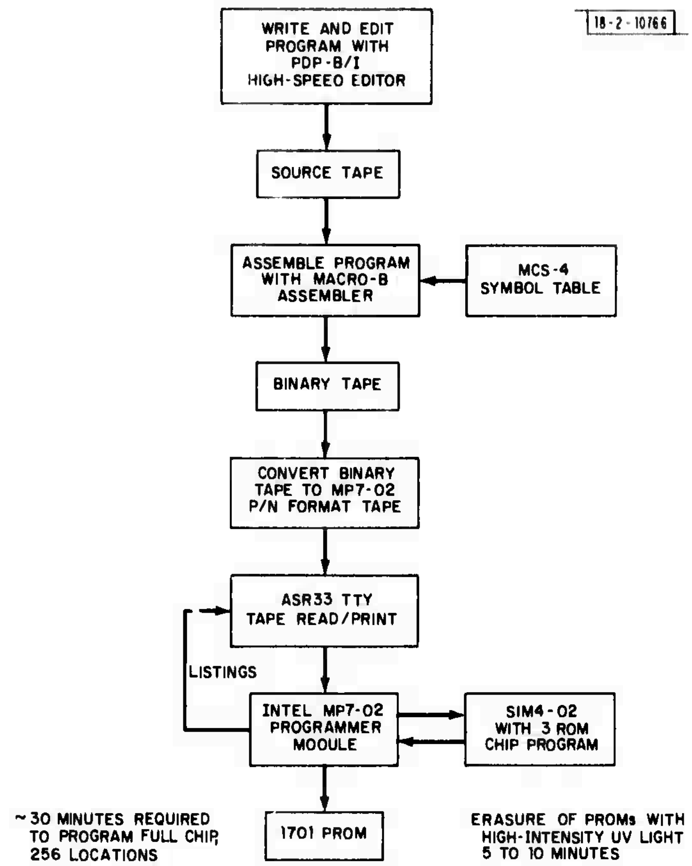

Fig. 3. Programming SIM4-02 PROMs.

Debugging of programs, loaded in PROMs and operating in a processor which offers no means of examining its internal registers, poses a problem. One possible solution to the problem is to insert debug instructions in the programs when they are written, to output program stage indicators via ports not used by the program, as flags of program activity. These indicators can be set at entrees to or exits from subroutines or at possible trouble spots within a routine. This approach is being tried and has been reasonably successful thus far.